DRAFT

DYNAMIC DENSITY:
THE MEASURE OF AIR TRAFFIC CONTROL SECTOR COMPLEXITY
FOR THE EN ROUTE ENVIRONMENT

Phase II

Experiment Plan

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

APPENDIXES

LIST OF ILLUSTRATIONS

Figure Page

Table

1. INTRODUCTION

In the present air traffic control (ATC) system, traffic management personnel use the Enhanced Traffic Management System (ETMS) 'monitor alert' parameter as a strategic planning tool to identify and predict sector traffic complexity. This parameter, based solely on aircraft count, identifies a sector complexity threshold. It is widely recognized, however, that this threshold measurement is often an insufficient and/or inaccurate prediction of sector traffic complexity. The Federal Aviation Administration (FAA), industry, and partners (through the RTCA Taskforce 3) have recognized the need to develop a better method to measure and predict complexity, referred to as Dynamic Density (DD), and are embarking on several research efforts to come up with a validated metric(s) to replace monitor alert.

Advanced concepts and programs aimed at improving the efficiency of the NAS, such as dynamic resectorization, free flight, the enhanced ground delay program, and airspace redesign all depend on the ability to accurately measure and predict the air traffic complexity at the sector level. If such measurements and predictions can be accurately made then the application and expected benefits of advanced concepts can be objectively determined. Since the current measure is inadequate to support these advanced concepts, clearly a better measurement of air traffic complexity is necessary.

1.1. The Need for Dynamic Density

The first DD technical exchange meeting was held in November 1997. Various organizations studying sector complexity were present including the William J. Hughes Technical Center's (WJHTC) National Airspace System (NAS) Advanced Concepts Branch (ACT-540), NASA Ames Research Center, CSSI Inc., CAMI, and CNA. Many of these organizations are attempting to develop tools and metrics to accurately determine and predict sector complexity based on various dynamic and static sector complexity characteristics.

1.2. Research Management Plan

In order to integrate all of the DD research efforts, the Architecture and System Engineering (ASD-130) and Air Traffic Services Operations Integration (ATP-420) tasked ACT-540 to develop a Research Management Plan (RMP) for the DD effort. The RMP describes the DD research phases, roles and responsibilities of participating organizations, and milestone/deliverable schedules (NAS Advanced Concepts Branch, 2000). The RMP is a living document that will be continually updated to reflect all of the activities as the research progresses.

To reduce costs and duplication of efforts, ACT-540 will conduct all DD research activities in conjunction with the partner organizations. ATP-420, ASD-130, and NASA Ames Research Center are the sponsors for the studies. The following pages detail a cohesive experiment plan that addresses the requirements for data collection and the study methodology practiced by each organization.

1.3. Program Objective

The overall purpose of the Dynamic Density program, as described in the RMP, is to develop, validate, and choose DD metric(s) that will measure and predict sector level air traffic complexity.

The specific goals of DD program are as follows:

a) Identify a set of DD variables (e.g., traffic density, complexity of flow) that contribute to air traffic complexity or ATC taskload, or the demands imposed on the task;

b) Quantify the contribution of these variables in the form of a weighted DD equation;

c) Validate the DD equation (e.g., how accurately it measures and predicts air traffic complexity); and

d) Identify critical DD values, or points at which actions are necessary to reduce or balance sector level complexity (e.g., add a controller to meet task demands).

2. BACKGROUND

Although the term 'Dynamic Density' is relatively new, the factors that contribute to sector level traffic complexity have been of interest to researchers for a long time. In a literature review of sector complexity, Mogford, Guttman, Morrow, and Kopardekar (1995) identified and reviewed air traffic complexity-related literature dating back to 1963. Most articles cited aircraft count, sector geometry, traffic flows, separation standards, aircraft performance characteristics, and weather as the most common factors that contribute to air traffic complexity or difficulty. A more recent review of the list of contributing factors is described in Kopardekar (2000).

2.1. Definition of Dynamic Density

The definition of 'Dynamic Density' has several variations. DD is analogous to air traffic complexity or difficulty of a situation. DD is “a measure of control-related workload that is a function of the number of aircraft and the complexity of traffic patterns in a volume of airspace” (Laudeman, Brasil, & Branstrom, 1996). For the purposes of the research described herein, a more comprehensive definition of DD states that it is *a collective effect all factors that contribute to the sector level air traffic control complexity or difficulty*. It is a measure of ATC taskload and is the basis of controller subjective workload (NAS Advanced Concepts Branch, RMP, 2000).

2.2. Operational Benefits and Applications of Dynamic Density Metric

A validated DD metric has many potential operational benefits. The metric would:

- *Provide a more accurate measure of sector complexity than the current ETMS monitor alert*, which uses only aircraft count to predict sector level activity or complexity. It is widely recognized that this approach is often insufficient or inaccurate. For example, 5 aircraft with converging flight paths create a different level of complexity than 5 aircraft separated each by 20 miles. Monitor alert does not recognize or understand this difference, however, a DD metric would.

- *Identify and predict situations when air traffic complexity will increase such that airspace resectorization would be recommended*. The DD metric will predict when air traffic complexity warrants resectorization of airspace to balance air traffic controller workload, peak traffic flows, and traffic flow changes due to events such as weather deviations and activation of special use airspace. Although a limited degree of resectorization is available today (e.g., combining sectors for midnight shift), the DD metric will be useful for strategic airspace management on a much broader scale.

- *Provide a means of planning sector staffing more efficiently*. With a more accurate prediction of air traffic complexity, controller staffing of sectors can be planned more efficiently.

- *Support future free flight concepts and identify situations when free flight operations, such as shared-separation authority, should be limited*. The DD metric will help determine the level of airspace complexity during free flight activity. It will signal when the level of free flight activity and/or user preferred routes should be restricted to reduce or balance the complexity, thus enabling better traffic flow management.

- *Support airspace redesign efforts and user-preferred initiatives*. One of the objectives of the strategic airspace redesign efforts is to balance the complexity of air traffic by redesigning sectors and traffic flows within sectors. The DD metric will provide an objective assessment of the impact of airspace redesign on complexity with specific sectors and the entire NAS.

The ability to accurately measure and predict the sector level complexity has a number of potential benefits that include increased flexibility, capacity, predictability, and safety through the applications described above. Figure 1 summarizes the applications, requirements, and potential benefits of DD metric(s).

As described in the RMP, DD is a multi-year, multi-phase program. ACT-540 researchers have completed Phase I of the DD program. The purpose of this research plan is to describe Phase II of the DD effort.

3. PHASE I - PILOT STUDY

The following subsections describe the Phase I background, objectives, method, results, and subsequent recommendations for Phase II.

3.1. Phase I Overview

The Phase I DD study was conducted at the Denver Air Route Traffic Control Center (ARTCC) in Longmont, Colorado, October 26-27, 1999. Prior to the conduct of Phase I, ACT-540 and Titan Systems researchers worked with personnel from Denver ARTCC to select six

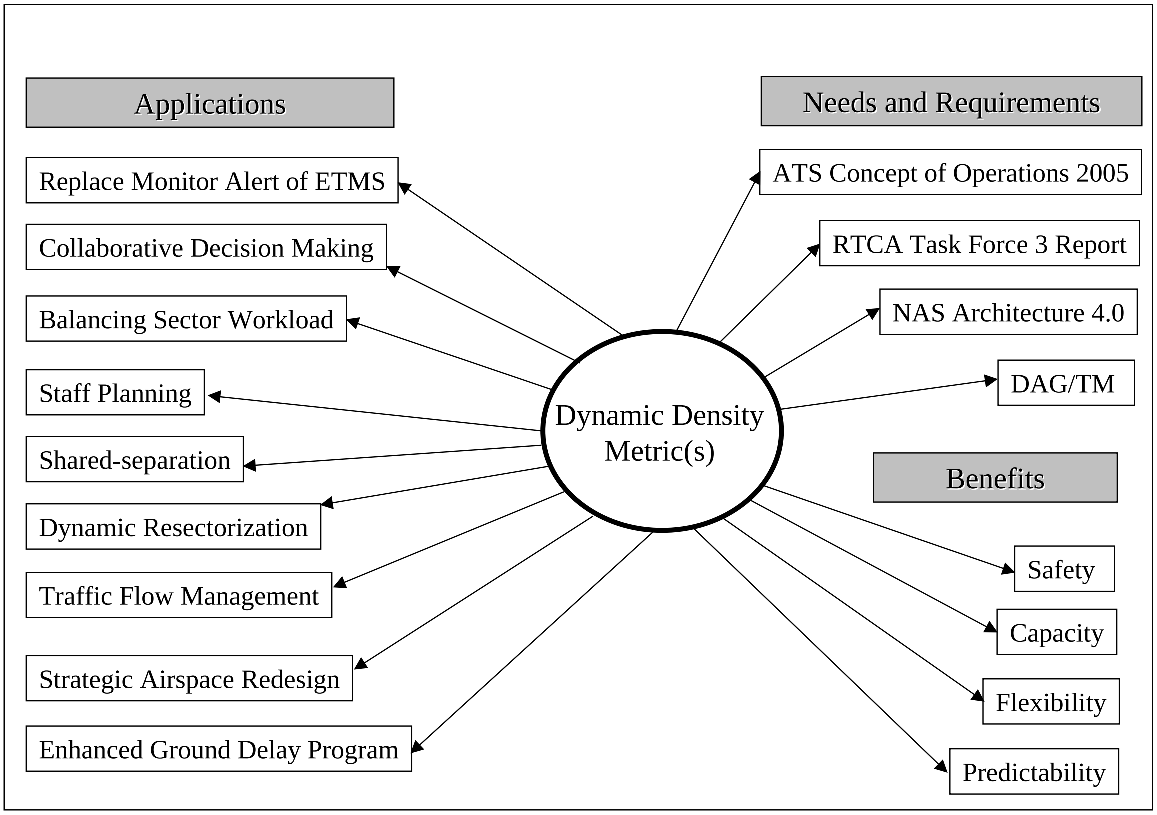

Figure 1. Potential applications, requirements, and benefits of a DD metric(s).

traffic samples from Area 4's high-altitude Sector 25 on two different days in August 1999. The samples represented decreasing, steady, and increasing traffic flows over 40-minute time periods. These samples were replayed with voice during the conduct of Phase I using a Systematic Air Traffic Operations Research Initiative (SATORI) system. Each sample was replayed twice in random order, thereby providing 12 scenarios. Participants were asked to provide air traffic complexity ratings, on a 1-7-point scale (1= Very Low, 4 = Moderate, and 7=Very High), at 4-minute intervals using electronic keypads. Additionally, at the end of each replay run, the participants completed questionnaires that addressed the factors contributing to complexity in each particular run. At the end of each day, participants verbally shared their opinions on various issues in a group debriefing session.

3.2. Phase I Objective

Phase I was a pilot study for Phase II. The researchers conducted Phase I as a low-cost means to evaluate and refine the proposed experimental approach for the large-scale Phase II data collection effort. The researchers were interested in evaluating the following study parameters:

- Types of traffic scenarios

- Duration of traffic scenarios
- Number and types of participants
- Frequency of complexity ratings
- Use of SATORI vs. active participant air traffic control

Although the primary purpose of Phase I did not involve evaluating any of the DD metrics, the researchers did obtain initial feedback on the DD concept, which provided additional data with respect to experimental design issues. They accomplished this through the collection of scenario complexity ratings and debrief sessions with the study participants. The researchers analyzed the data to answer the following questions:

- Is there a difference between controller and supervisor complexity ratings?
- Do different controllers provide consistent complexity ratings?
- Do different supervisors provide consistent complexity ratings?
- Do controllers provide consistent complexity ratings for the same traffic scenario between different trials?
- Do supervisors provide consistent complexity ratings for the same traffic scenario between different trials?
- Are participant responses consistent for the complexity factors involved in different traffic scenarios?

3.3. Phase I Results

Overall, the Phase I study was very successful. The following recommendations for Phase II were developed:

- Shorten the traffic sample duration from 40 minutes to 30 minutes.
- Show each traffic sample only once. There is no need to repeat the same traffic sample since the participants provided reliable ratings for two replications.
- Include weather situations in some of the traffic samples. The researchers did not include weather in the Phase I study in order to keep the study design simple.
- Reduce the complexity rating intervals from 4 minutes to 2 minutes. After discussions with NASA and Metron, the researchers agreed to obtain more data points by increasing the number of ratings collected.
- Collect a variety of traffic samples from multiple sectors and facilities. The researchers will collect decreasing, steady and increasing traffic samples while ensuring that all of the traffic samples cover moderate or high complexity situations.
- Coordinate a larger sample of supervisor and controller participants, if possible.
- Eliminate the collection of complexity factor rankings in Phase II. The participants indicated that the ranking of factors that contribute to complexity was confusing. For

Phase II, the participants will offer their own complexity factors for each traffic sample instead of picking from a list of predetermined factors.

The DD Phase I test report describes the approach and results in detail (Magyarits & Kopardekar, 2000).

4. PHASE II - INTRODUCTION

The Phase II researchers include ACT-540, Titan Systems, Metron, and NASA Ames Research Center. ACT-540 and Titan Systems have the primary responsibility of designing and conducting the Phase II data collection. All organizations, however, will participate in the Phase II metric development and validation activities. The National Air Traffic Control Association (NATCA) will be apprised of all research activities. ATP-400 and ASD-130 will sponsor the study.

4.1. Phase II Scope

Phase II will focus only on the en route domain. High and low-altitude sectors from various ARTCCs and a variety of traffic and weather situations will be included. With respect to the analysis activities, all proposed DD variables/metrics will be evaluated and validated.

4.2. Phase II Objectives

The objectives of DD Phase II effort are as follows:

1. Collect data from different facilities that covers a variety of traffic- and weather-related conditions to represent a range of air traffic situations experienced by controllers,
2. Develop a DD metric(s) calculation system that will dynamically compute DD measurements for the different traffic samples collected in (1),
3. Validate computed DD metric(s) by comparing them with controller and supervisor complexity ratings,
4. Determine if different metrics can predict critical points of adding/removing controllers to the sector positions as defined by a complexity threshold,
5. Compare different DD metric(s) on the ability to measure complexity,
6. Combine DD metric(s), if necessary, to develop the most accurate metric,
7. Compare DD metric(s) with current ETMS monitor alert complexity predictions, and
8. Provide recommendations for a DD metric(s) and identify its strengths and weaknesses in predicting air traffic complexity for different time periods (e.g., 12, 10, 8, 6, 4, 2, 1, 0.5, 0.25, 0.125 hours prior to specified time).

5. PHASE II - METHOD

The Phase II experiment will consist of multiple steps that are described in the following subsections. The steps are:

Step 1 - Compile list of DD variables comprising each DD metric

Step 2 - Develop software programs to compute each DD metric

Step 3 - Select sites for DD Phase II study and invite participation

Step 4 - Coordinate with sites to collect preliminary study data

Step 5 – Identify traffic scenarios, archive associated data, and create SATORI tapes

Step 6 – Replay SATORI and collect complexity ratings from controller and supervisor participants

Step 7 - Compute DD metrics for each traffic scenario

Step 8 - Validate metrics by comparing to complexity ratings

Step 9 - Compare metrics for accuracy

Step 10 - Provide recommendations to agency for a DD metric

The following diagram describes the sequence and relationship of the above activities using a step-on-the-node method. For example, the figure indicates that Step 4 cannot begin until Steps 1 and 3 are completed. It also indicates, however, that Step2 is an activity that will be performed in parallel to other activities.

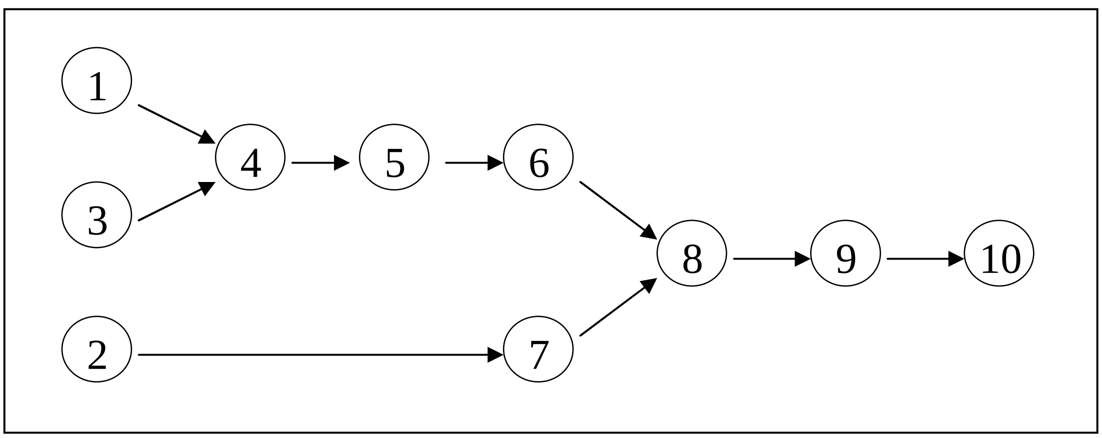

Figure 2. Sequence of steps for Phase II.

5.1. Step 1 - Compile list of DD variables comprising each DD metric

The researchers conducted a literature review of all DD-related research to extract all the variables that comprise the various DD metrics. The product of this step was a consolidated list of complexity-contributing variables that will be considered for validation. The results of this activity are detailed in a document entitled "Dynamic Density - A Review of Proposed Variables" (Kopardekar 2000).

5.2. Step 2 - Develop software programs to compute each DD metric

Software programs will be developed to compute each DD metric. At present, the WJHTC researchers and programmers are in the process of developing a system that will compute the ACT-540 DD variable. NASA researchers currently have a system that will compute the NASA and Metron DD variables. It is likely, however, that one software program will be used to compute all of the DD variables following Phase II.

5.3. Step 3 - Select sites for DD Phase II study and invite participation

Since the goal of the DD program is to develop a generic metric that can be used by any ARTCC, the data should be collected from sites that represent the different characteristics of the NAS. Therefore, ACT-540 researchers discussed the site selection with subject matter experts, national DD NATCA, Metron, and NASA Ames researchers. Taking into consideration the types of traffic flows, traffic load, in-trail restrictions, weather, military activity, mix of aircraft; and data collection requirements; the group decided that five sites (ZDV, ZFW, ZTL, ZLA, and ZOB) would be sufficient to cover a wide range of operations. These sites and their characteristics are summarized in Table 1.

Table 1: Dynamic Density Phase II Sites

Site and region	Characteristics
Denver ARTCC (**ZDV**), Northwest Mountain Region	Moderate to heavy traffic, weather (thunderstorms and winds), reroutes, terrain, some military activity, CTAS site, and DD Phase I site
Fort Worth ARTCC (**ZFW**), Southwest Region	Heavy traffic, highly transitional traffic, weather and reroutes, heavy overflight activity, some military activity, and CTAS site.
Atlanta ARTCC (**ZTL**), Southern Region	Heavy traffic, highly transitional traffic/regional hubs, weather (thunderstorms) and reroutes, weather fronts, general aviation traffic, complex traffic mix, and CTAS site.
Los Angeles ARTCC (**ZLA**), Western Pacific Region	Moderate to heavy traffic, heavy military activity, heavy general aviation activity, west coast, international flights, and CTAS site.
Cleveland ARTCC (**ZOB**), Great Lakes Region	Heavy traffic, significant miles-in-trail restrictions, heavy box-hauler traffic, weather, and feeds to ZNY and ZAU.

The ACT-540 researchers will visit each ARTCC, brief Phase II to various management, automation, traffic management, quality assurance, and NATCA personnel, and invite participation in the study. Specifically, the briefing will include a description of the project background, objectives, data collection requirements, and other relevant information related to the study. A facility point of contact (POC) will be established at the briefing for coordination between the facility and the WJHTC.

5.4. Step 4 - Coordinate with sites to collect preliminary study data

5.4.1. Sector and traffic scenario selection

With specific directions provided by ACT-540, the POC will be asked to identify 18 thirty-minute traffic samples from his/her facility. The goal is to select samples from 3 areas within each facility, then from 3 sectors within each of those areas, and finally, 2 traffic scenarios for each sector. Figure 3 depicts this sampling strategy. Appendix A contains the sample selection checklist that each facility will receive. Care will be taken to collect these samples such that they include increasing, decreasing, and steady traffic. The researchers will also ensure that some of the traffic samples contain weather, SUA activation, reroutes, and varying levels of traffic. These and other characteristics of traffic and sector will help identify the similarities and differences among sectors across the selected facilities.

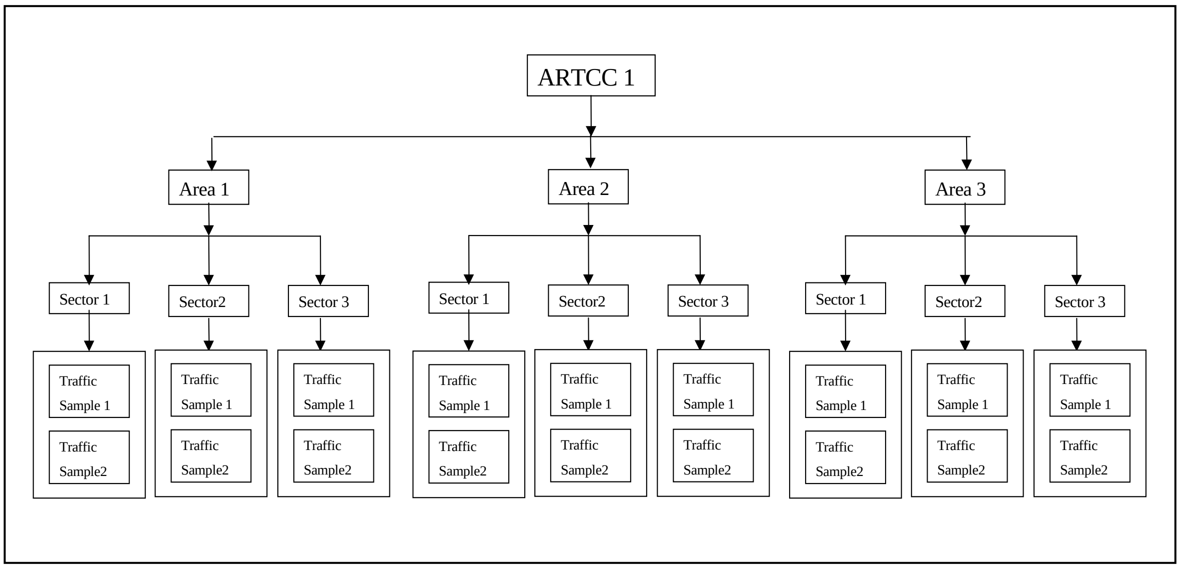

Figure 3. Sampling strategy at each site.

5.4.2. Data collection for study preparation and scenario development

The POCs will compile a variety of data from each facility, as described in Table 2. Some of the data will be used in test development activities and some will be used in the metric development and analysis activities.

Table 2. Data Collection Requirements

Data	Description	Method of collection	Source	Responsibility
Command Center logs	Traffic flow restrictions	???	Command Center database	ACT-540

Data	Description	Method of collection	Source	Responsibility
CM_Sim File[1]	CTAS basic data	Copy from facility or NASA (to be decided based on each site)	CTAS equipped facilities only. (Need to convert SAR data for non-CTAS equipped sites).	ACT-540, Metron, and facility POC
Letters of Agreement (LOAs)	For the entire facility	SOP	Each facility	ACT-540 representative
Adaptation Control Environment System (ACES) Input Tapes	For the entire facility (when the initial data is being collected)	ACES tape	Each facility	ACT-540 representative
ACES Output Tapes	For the entire facility (when the initial data is being collected)	ACES tape	Each facility	ACT-540 representative
Locations and Type of Surveillance Equipment	Latitude/longitude and type (e.g., ASRS4).		Each Facility	ACT-540 and facility POC
Unavailable Airspace	1. Active special use airspace will be identified by name. 2. SMEs will estimate locations unavailable due to weather during SATORI playbacks of scenarios. Locations will be described in latitude/longitude and altitude whenever possible.	Facility SOP or discuss with SME	Each facility	ACT-540 and facility POC
Sector Configurations, Sector Boundaries	1. Name, latitude/longitude, and altitude of sectors when de-combined.		Each facility	ACT-540 and facility POC

[1] CM_Sim files can be collected only at CTAS-equipped sites. At the time of this plan, only ZDV and ZFW were equipped with CTAS. ZLA and ZTL are anticipated to be equipped with CTAS by the time Phase II reaches them. Please see the flow chart on the next page for a summary of the CM_Sim file data generation method.

Data	Description	Method of collection	Source	Responsibility
	2. A description of likely times for sector combinations. 3. Description of the configurations run during the study.			
Neighboring Sectors and Facilities	From SOP, LOAs, etc.		Each facility	ACT-540 and facility POC
Conflict alert look ahead time	Subject matter expert/ Automation specialist		Each facility	ACT-540 and facility POC
DSR action data	Record of all activities their frequency and duration		Each facility	ACT-540
Point of Tangency	Latitude/longitude.		Each Facility – ACES or NTAP	
Standard Operating Procedures (SOP)	For the 3 areas and 9 sectors that are selected	SOP	Each facility (3 areas)	ACT-540
Detailed map of airspace	For the entire facility but detailed for selected 9 sectors	Blue print, overhead maps from cartographer	Each facility (3 areas)	Facility POC
SUA areas	For the entire facility (Latitude, Longitude, and Altitude)	SOP	Each facility (3 areas)	ACT-540
SAR tapes	For 18 thirty-minute traffic samples (2 from each sector)	Within 15 days of actual traffic operations	Each facility (Quality Assurance Dept.)	ACT-540 and facility POC
Audio tapes	Corresponding to SAR tapes (18, 30-minute voice tapes matching SAR tapes)	Within 15 days of actual traffic operations	Each facility (Quality Assurance Dept.)	ACT-540 and facility POC
Sign In/Sign Out logs	For 18 30-minute traffic samples (2 from each sector)	Supervisor log	Each facility (Supervisor workstation)	ACT-540 and facility POC
Monitor alert parameter for all selected sectors	Identify the current complexity threshold	Facility TMU record	Each facility (TMU)	ACT-540 and facility POC
Monitor Alert	Identify when the	Monitor alert	Each facility	ACT-540 and

Data	Description	Method of collection	Source	Responsibility
Logs	monitor alert parameter is exceeded	log	(TMU workstation)	facility POC
Traffic Management Unit Logs	Examine the mile-in-trail and other restrictions	TMU log	Each facility (TMU workstation)	ACT-540 and facility POC
Winds Aloft	12 hour forecast for speed and direction of wind at given altitude.	???	Each Facility meteorologist, NWS	???
Fix Locations	Latitude, longitude and names.		Each Facility, National Database, ACES for all 18 sectors	ACT-540 and facility POC
Merge Points	Merge points of traffic streams given in latitude/longitude or fix, and altitude.		Each Facility, SOP	ACT-540 and facility POC
Preferred Flow Direction	Orientation of traffic through the sector based on the 8 cardinal points of the compass (e.g., North, South, etc.).		Each Facility, SOP	ACT-540 and facility POC
Terrain Elevation	Includes minimum vectoring altitudes (MVAs), minimum en route altitudes[2] (MEAs), and minimum obstruction clearance altitudes[3] (MOCAs).	???	JEPPESEN/ Each Facility	ACT-540
Airway Locations, Jet Routes	Each will be described by the navigational aids that comprise them.		JEPPESEN	ACT-540 and facility POC
VOR/DME Locations	Latitude/longitude.		National Database	ACT-540 and facility POC
Aircraft Parameters	Time (hh:mm:ss), [x,y] (nautical miles), altitude, ground speed, and track heading for the duration		SAR, CM_Sim file and ETMS	ACT-540, Metron, and ATA-200

[2] Defined as the lowest altitude an aircraft can fly and still be able to receive a signal.

[3] Defined as the lowest altitude an aircraft can fly.

Data	**Description**	**Method of collection**	**Source**	**Responsibility**
	of the run.			
Aircraft Descriptions	Fields 1, 3, and 4 of the flight plan will give aircraft call sign, type, and equipage. A table from the 7110.65 will be provided to determine additional aircraft descriptions (i.e., heavy, and engine types).		SAR, CM_Sim file and ETMS	ACT-540, Metron, and ATA-200
Filed Flight Plans and amendments	All flight plan data as filed by airline including route of flight, airspeed, cruise altitude, etc.		SAR, CM_Sim file and ETMS	ACT-540, Metron, and ATA-200
Conflict Alert	Time, aircraft pair, and type of conflict.		SAR, CM_Sim file and ETMS	ACT-540, Metron, and ATA-200
Minimum Safe Altitude Warning	Time, aircraft call sign, and location for each warning.		SAR, CM_Sim file and ETMS	ACT-540, Metron, and ATA-200
Flight plan and route information	Time, altitude, speed, position, and other details for aircraft that may or may not be available using SAR. Predictive information from ETMS database. (12, 10, 8, 6, 4, 2, 1, 0.5, 0.25, 0.125 hour predictions of aircraft positions)		SAR, CM_Sim file and ETMS	ACT-540, Metron, and ATA-200
Aircraft position predictions	Predicted position of aircraft with 5, 10, 15, and 20 minutes look ahead		CM_Sim file	Metron
CTAS facility origin location	Position of CTAS origin's latitude and longitude. Since CTAS is still evolving, the origin location could change, therefore origin information must be documented.		CTAS support	ACT-540

Data	**Description**	**Method of collection**	**Source**	**Responsibility**
Weather Data (e.g., Cloud Ceiling, Surface Temperature)	Any weather data contained in the sequence report will be given in the NWS format. Rapid Update Cycle (RUC) data (from NOAA's database)	**NEED TO FIGURE OUT – Facility Meteorologist??**	Sequence Reports, National Weather Service (NWS)	ACT-540

The sites selected to participate in Phase II have varying levels of equipage/capabilities, as shown in Table 3.

Table 3. Phase II Site Equipage

Facility	**HOST (SAR data)**	**CTAS Build 2**
Fort Worth (ZFW)	✓	✓
Denver (ZDV)	✓	✓
Los Angeles (ZLA)	✓	✓
Atlanta (ZTL)	✓	✓
Cleveland (ZOB)	✓	N/a

CTAS Build 2 provides aircraft prediction-related information, which is an essential component for the DD metric analysis. Specifically, CTAS records aircraft positions in a file format called CM_Sim. The Build 2 version of CTAS generates CM_Sim files with 'optional parameters', a subfile that contains aircraft position predictions (i.e., 5, 10, 15, and 20 minute predictions). These optional parameters are essential for the calculation and validation of DD metrics. At the sites where CTAS is not available, the CM_Sim file and optional parameters can be generated with additional software using SAR data. Figure 4 illustrates the activities and the decision-making process that are involved in collecting CM_Sim files and optional parameters, either from CTAS or using SAR data.

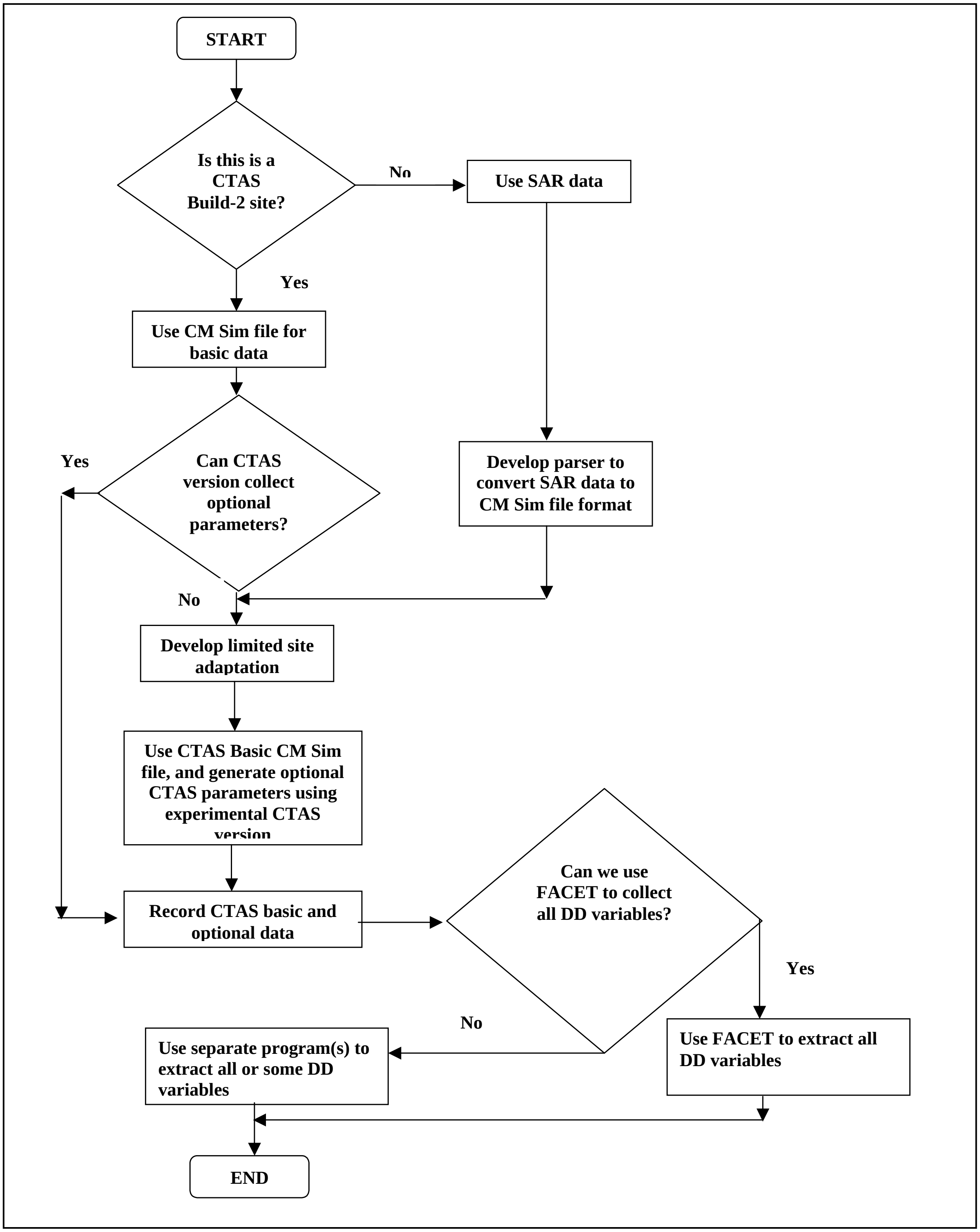

Figure 4. Collection of DD metrics from SAR and CTAS CM_Sim files.[4]

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[4] Future ATM Concept Exploration Tool (FACET) is a tool developed by NASA Ames Research Center.

5.4.3. Relationship of DD metric prediction accuracy with time

One of the objectives of Phase II is to examine the relationship of the prediction accuracy of different DD metrics with time. The goal is to calculate DD predictions 12, 10, 8, 6, 4, 2, 1, 0.5, and 0.25 hours ahead of time and compare the accuracy with real-time, actual DD metric values. The comparison of the prediction accuracy with time will provide crucial information about the strength of the DD predictions.

CTAS and Host data contain aircraft information (e.g., flight plans) up to 4 hours prior to departure, provided that the aircraft are within the boundaries of the Center. However, if an aircraft is transferred from one ARTCC to another ARTCC, then that aircraft's information is sent to the receiving ARTCC only 30 minutes prior to the aircraft's entry into that ARTCC's airspace. This limits the prediction data for the DD metric to within a 30-minute timeframe. However, ETMS data contains information related to aircraft flight plans up to 12 hours prior to departure[5]. If amendments are made to the flight plans (e.g., due to weather), they are updated as necessary. Therefore, to evaluate prediction accuracy over time, ETMS, CTAS, and SAR (Host) data all must be examined.

5.5. Step 5 - Identify traffic scenarios and archive associated data

SAR data and the corresponding audiotapes will be converted to SATORI format for playback to the Phase II participants. Voice tapes must also be integrated with the SATORI files. The following are three ways to convert SAR to SATORI. They are listed in order of preference, considering the conversion can be a cumbersome process.

1. Convert SAR data into SATORI-ready files using Host patches (similar to ZDV process employed in Phase I),
2. Convert SAR data directly into SATORI-ready files using Metron's software, or
3. Convert SAR data into SATORI-ready files using DART runs.

The researchers will request assistance from each facility to develop the SATORI files. All 18 thirty-minute traffic samples will be converted to SATORI with audio. Additionally, one 20-minute training sample will be created or copied from an existing SATORI file for each Area for a total of 3 training samples per facility.

5.6. Step 6 - Collect complexity ratings from controller and supervisor participants

5.6.1. Overall purpose

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[5] ETMS data has some limitations. For example, aircraft position is only reported every 4 minutes, therefore accuracy of data is within +/- 2-4 minutes. Also altitude data may be inaccurate for certain aircraft (e.g., transitioning aircraft).

Once the SATORI files are prepared, the researchers will schedule the complexity rating data collection activity at each facility. The purpose of this part of the study is to collect subjective complexity ratings from controllers and supervisors (and possibly TMU personnel) to correlate and compare to the DD metric calculations and to build the metrics. The participant ratings will be collected at 2-minute intervals over each 30-minute traffic sample using electronic keypads.

5.6.2. Number and type of participants

From each ARTCC, the researchers are requesting that at least 3 supervisors and 3 air traffic controllers from each of 3 Areas participate in the study. If all facilities can meet this request, the total number of participants will be 90. The larger the number of participants, the more representative the sample will be. An equal number of supervisor and controller participants is desired but is not mandatory for the study.

5.6.3. Equipment

The equipment for Phase II will consist of a SATORI system (with voice) at each facility, a projector to display the SATORI, complexity rating keypads, and two laptop computers.

5.6.3.1. SATORI System

SATORI will be used to present the traffic samples to the participants. It is designed to realistically replay ATC operations using data recorded from actual field operations. The SATORI system replays the controller radar screen view as it appeared during live operations and also replays air-ground and ground-ground communications. SATORI playbacks include all traffic in and around the sector and all on-screen weather information. SATORI collects data on sector and traffic variables and can be modified to collect additional variables.

5.6.3.2. Complexity Rating Keypads and Laptop Computers

Complexity rating keypads will be used to collect participant ratings electronically. They consist of small, square buttons with numbers ranging from 1 to 7 (corresponding to a 1-7-complexity scale) that will illuminate every two minutes during a traffic sample presentation. The keypads contain tone generators that sound concurrently with the keypad illumination. At those prompts, participants will enter ratings corresponding to the complexity of the traffic sample at that point in time. The button lights will automatically extinguish after 20 seconds if a participant does not provide a complexity rating and a default 'no entry' code will be recorded. The keypads will be connected to PC-compatible laptops through the serial ports. Up to four complexity rating keypads can be connected to one laptop. The computers will control the timing of the prompts and record the participants' responses in a database file, which can be downloaded for analysis.

5.6.4. Procedure

At each ARTCC, participants representing one specialization area will participate for one day. Ideally, the entire data collection activity for one site will span over 3 days, a day for each area. If all participants from one area cannot be accommodated on a single day due to scheduling conflicts or room size limitations, then the data collection will be conducted over multiple days.

The supervisors and controllers will receive a briefing prior to participating in the study on the background and objectives of DD. After the briefing, the participants will complete a Consent Form (Appendix B), which will assure their anonymity and voluntary participation in the study, followed by a Background Form (Appendix C), which will collect information related to their ATC experience. After the forms are completed, the participants will be given a 20-minute training scenario to familiarize them with the data collection procedure.

For the data collection portion of the study, the participants will observe six 30-minute SATORI traffic samples (2 traffic samples from each sector) in random order. Each traffic sample observation is called a “run.” Upon completion of each run, the participants will be given 10 minutes to complete a Post Run Questionnaire (Appendix D), followed by a 10-minute break. After all six runs are completed, a debrief session will be conducted where participants will be able to discuss complexity issues involved with the traffic samples they experienced. Participants will also be allowed to discuss study methodology and give suggestions for further research. A detailed daily schedule is provided in Appendix E.

The researchers investigated both the merits and limitations of using SATORI versus human-in-the-loop simulations for presenting traffic scenarios. The details of their comparison are provided in the DD Phase I report (Magyarits & Kopardekar, 2000). The researchers opted to use SATORI because it provides the ability to display the exact same traffic situations to all participants. In a real-time, human-in-loop simulation environment, participants are engaged in and control simulated traffic differently, thus creating different and experimentally uncontrolled situations. Another advantage of SATORI is that it can be shown to a number of participants simultaneously. The researchers used a projection system for the Phase I study that projected SATORI traffic on a much larger screen thereby allowing the simultaneous collection of ratings and larger participation.

5.6.5. Participant Data Collection

As previously mentioned, participants will provide complexity ratings every two minutes using the complexity rating keypads or paper forms. In addition to the ratings, the participants will indicate on the same form, at the same two-minute intervals, the number of controllers that should be on position for that sector due to the level of complexity.

At the end of each run, the participants will complete a Post Run Questionnaire. They will be asked to identify specific factors that contributed to the complexity in that particular run. The participants will also be asked to provide an overall complexity rating and to characterize the traffic levels in the run (e.g., increasing, decreasing, steady). They will also be encouraged to record additional comments. Table 4 summarizes the participant data collection requirements.

Table 4: Participant Data Collection Requirements

Data Type	Frequency	Purpose
Consent Form	Between the initial briefing and the data collection	Inform participants about their rights and ensure voluntary participation.
Background Form	Between the completion of Consent Form and the data collection	Gather data related to participant experience, years at facility, and other demographic information.
Complexity Ratings	During each run, at two-minute interval	Collect subjective ratings of sector complexity from participants.
Number of Controllers on Position (due to complexity)	During each run, each time complexity rating is recorded (i.e., 2-minute intervals)	Collect subjective opinions about what level of staffing is necessary as a function of complexity at that moment.
Post Run Form	At the end of each run	Collect overall complexity ratings for the run and information related to the factors that contributed to the complexity.
Debriefing	At the end of each day	Generate discussions regarding complexity issues and gather feedback about the study.

5.7. Step 7 - Compute DD metrics for each traffic scenario

Data collected in Steps 4 and 6 will be distributed to ACT-540, NASA, Metron, and other interested organizations identified in the RMP. Upon receipt of the data, these organizations will compute their own DD metric(s) every two minutes in each traffic sample. The following two options are currently being considered for the calculation of the DD metrics:

1. Each organization (ACT-540, Metron, NASA, etc.) will separately compute its own DD metric using its own software.
2. All organizations will compute all of the metrics using a single calculation system.

NASA's Future Air Traffic Management Concept Exploration Tool (FACET) has older versions of NASA and Metron's DD metrics incorporated into its program. ACT-540 is in the process of developing a stand-alone software to compute its DD metric using some of CTAS's predictive capability. These individual software development efforts are essential for the computation of all of the different metrics. However, since the goal is to compare and contrast the different metrics, it would also be beneficial to compute all of the metrics using a single software system. To do this, ACT-540's program will also have to be integrated into FACET.

The researchers are currently investigating both options and will select the option that is practical, cost efficient and expeditious.

5.8. Step 8 - Validate metrics by comparing to complexity ratings

The different DD metrics will be compared with the complexity ratings collected from participant controllers and supervisors. Data collected in Step 4 will be split into two groups: Group A will consist of 66.66% of the data and Group B will consist of the remaining 33.33% of the data. From each facility, 12 samples will comprise Group A and 6 samples will comprise Group B. The division of the data from the 18 traffic samples from each facility will be completely random.

5.8.1. Group A Data - Metric Development Process

Group A data will be used to build/develop the metrics as proposed by different organizations (ACT-540, Metron, and NASA). For this activity, multiple methods will be considered (linear and non-linear regression, neural networks, genetic algorithms, etc.). The Group A data will be compared with the corresponding complexity ratings to develop weights of the individual variables that compose the aggregated metrics of each organization. This effort will generate DD equations that will be used to compute DD metric values in the validation stage.

5.8.2. Group B Data - Metric Validation Process

Group B data will be used to compute the DD metrics at two-minute intervals using the DD equations developed in Step 2. After the DD metric predictions are generated, they will be compared to participant complexity ratings from Group B.

The comparison of the DD metric predictions and complexity ratings from Group B will determine the accuracy and validity of the DD metrics. Statistical information (e.g., correlation coefficient, variance, mean, closeness of fit, level of significance) will be produced to validate the different metrics.

The researchers will also closely scrutinize the contribution of the individual variables to the overall metrics. This can be done by multiple ways. One of easiest ways is to examine the coefficients of the variables (or weights) and conduct tests of significance to determine if the coefficients are different than zero. This is commonly practiced in regression analysis.

The researchers will also compare the complexity at critical points, such as when a participant indicated he/she would add or remove a controller, with the DD metrics at the same time to examine if the metrics can measure the complexity accurately to predict such critical points.

ACT-540, NASA, and Metron researchers will work together closely to identify different statistical methods and underlying details so that the validation process will be consistent across all organizations. Researchers may also attempt to use multiple methods (e.g., linear, non-linear regression, neural networks, and genetic algorithms) to determine if one method is preferred over another.

The final report will describe in detail the methods used to develop the unified DD equation and how the weights for each of the DD variables were derived.

5.8.3. Step 9 - Compare metrics for accuracy

Once the metric equations are developed, the predicted DD values will be compared with each other (in addition to comparisons with the complexity ratings) to determine accuracy and sensitivities. The accuracy will be determined by how close the computations are to the complexity ratings and how well they predict complexity as a function of time. The metric that is best will measure the complexity accurately as compared with the complexity ratings under all traffic conditions (i.e., the metric must be sensitive to changes in complexity). Figure 5 shows a block diagram of the metric comparison process.

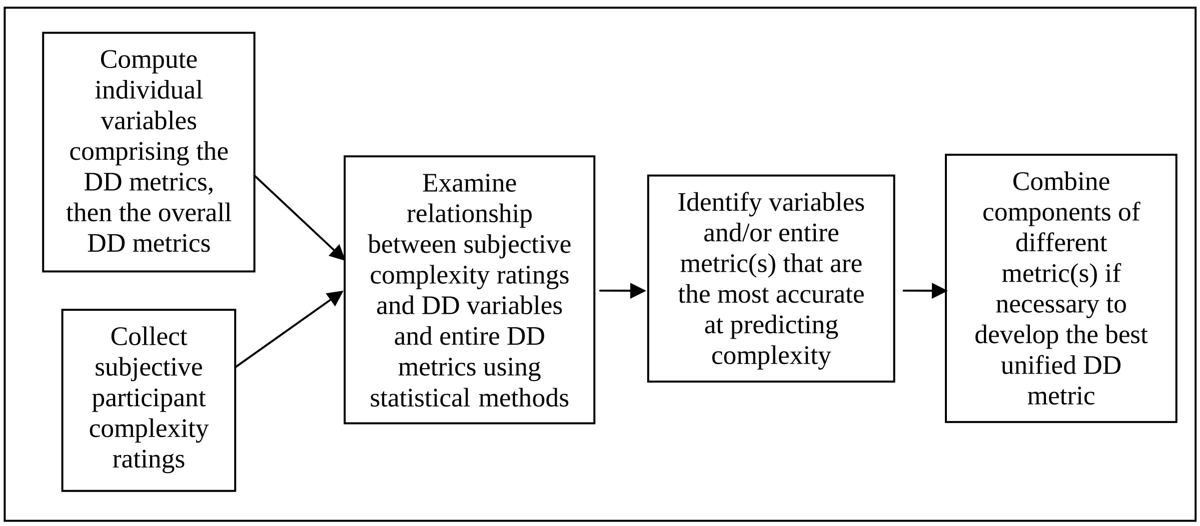

Figure 5. Metric comparison and enhancement process.

The researchers will conduct the following comparisons using the appropriate statistical techniques:

1. *Comparison of different metrics with complexity ratings*.

   In this analysis, different metrics (e.g., NASA, Metron, WJHTC/ACT-540) including the involved individual variables and the collected complexity ratings will be compared. These comparisons will indicate how well each metric measures complexity as compared with the ratings.

2. *Comparison of different metrics and the individual variables for 'instantaneous' accuracy.*

   These comparisons will identify the specific strengths and weaknesses of each metric and the involved variables. The information will be useful if a new metric must be developed that is composed of multiple metrics from different organizations. It will also identify how different metrics perform for different traffic complexity levels (i.e., sensitivity of each metric with respect to complexity level).

3. *Comparison of different metrics and the individual variables for 'predictive' accuracy.*

   This analysis will be conducted comparing the DD metric predictions (i.e., *10, 8, 6, 4, 2, 1, 0.5, 0.25, 0.125 hours in advance)* with the complexity ratings and the actual DD metric values as computed by each organization (i.e., NASA, Metron, ACT-540).

4. *Comparison of different metric thresholds with 'monitor alert' thresholds for different sectors*.

   In this comparison, the complexity ratings and DD metric thresholds (i.e., critical DD values determined for specific sectors) will be compared with monitor alert thresholds. The examination will reveal if the metrics or the monitor alert thresholds are better at predicting complexity.

Statistical techniques, such as regression, correlation, mean square root, descriptive statistics (mean, mode, median, standard deviations, range), ANOVA, and other methods will be employed to determine the comparisons. Additionally, researchers will generate tables and graphs for illustration purposes.

5.8.4. Step 10 - Provide recommendations to agency for a DD metric

Based on the results of the different comparisons, the researchers will 1) develop recommendations with respect to the strengths, weaknesses, and operational utility of the different metrics; 2) select the best metric(s); 3) generate ideas for further research regarding, for example, DD metric prototyping and terminal DD research activities. These recommendations will correspond to the results of Steps 8 and 9 and will also include a description of the lessons learned from Phase II.

6. PHASE II - SCHEDULE

Table 5 provides a master schedule for the DD Phase II effort.

Table 5. Master Schedule for DD Phase II

Milestone	Schedule
1. Develop an experiment working group of all participating research organizations	May 2000
2. Develop DD metric calculation software	May 2000 – March 2001
3. Acquire initial feedback on the study approach from the national NATCA representative	June 2000
4. Develop contractual arrangements with working group participants	July 2000
5. Develop MOU between NATCA, ATX, and ATP	July 2000

Milestone	Schedule
6. Identify POCs at each facility	January 2001
7. Provide briefings on the study and data requirements to all five facilities	July 2000- December 2000
8. Collect initial data from all five facilities	October 2000- August 2001
9. Prepare SATORI tapes for all traffic samples at each facility	October 2000 - September 2001
10. Collect complexity ratings at each facility	April 2001 - September 2001
11. Generate DD metric(s) for all traffic samples	June 2001 - October 2001
12. Conduct validation tests	June 2001 – October 2001
13. Compare all metrics to select the best one or develop combined metric	August 2001 – October 2001
14. Prepare preliminary report	November 2001
15. Finalize report	January 2002

The individual site schedules are provided in Table 6.

Table 6. Schedule at Individual Sites

Milestone/Activity	ZFW	ZDV	ZLA	ZTL	ZOB
Develop facility point of contact	X	X	X	X	X
Brief facility point of contact, NATCA representative and other staff regarding Phase II objectives and data collection requirements	X	X	X	X	X
Collect initial data	X	X	X		
Develop SATORI tapes	X	X	X		
Collect complexity ratings		X			
Conduct analysis of complexity ratings and DD metrics					
Make recommendations in a preliminary report					

7. PHASE II - RISKS AND MITIGATION STRATEGIES

The DD Phase II effort is a multi-organization, data- and resource-intensive study. Therefore, certain risks could be experienced. Table 7 describes known risks and the associated risk mitigation strategies.

Table 7: Known Risks and Mitigation Strategy

Risk	Category	Mitigation Strategy
Lack of adequate funding	Programmatic	ACT-540 is working closely with ATP-400 and ASD-130 to ensure that there will be adequate funding to complete the study. The funding requirements include contractor support, equipment, facility backfill and/or overtime, and travel expenses.
Participant and/or union anonymity concerns due to SATORI traffic and voice data requirements	Operational	ACT-540 will work closely with ATP, ATX, and NATCA to generate a Memorandum of Understanding (MOU) among concerned parties (Appendix F). This may involve providing immunity to any errors noticed while watching the SATORI tapes, as applicable. A similar MOU was developed for the DD Phase I study.
Lack of adequate facility participation for initial and/or participant data collection due to scheduling conflicts and/or resource limitations	Operational and programmatic	ACT-540 will work closely with ATP, ATX, national and local NATCA representatives, and facility staff to develop a realistic schedule for each facility. ACT-540 will clearly describe facility requirements to the facility POC and other staff. A close coordination will be maintained between facility representatives to quickly identify potential changes in schedule.
Lack of CTAS support	Operational	Although CTAS data will be collected, continuous facility CTAS support is not anticipated. Both Metron and NASA researchers have a basic understanding of CTAS and will provide CTAS functional support as necessary.
Data collection problems (e.g., missing data, lost data, inadequately collected data)	Operational	All researchers will work closely with facilities to collect the data and maintain the data integrity. Since the data is the key component of this study, every effort will be made to properly collect, store, label, secure, and back-up data.

8. ROLES AND RESPONSIBILITIES

8.1. NAS Advanced Concepts Branch

The NAS Advanced Concepts Branch (ACT-540) (POC: Sherri Magyarits) and its support contractor Titan Systems (POC: Parimal Kopardekar) are responsible for the following:

- Overall management of the project,
- Development of the experiment plan,
- Close coordination with and responsiveness to ATP-400 and ASD-130 to ensure needs are satisfied,

- Coordination with facilities, national and local NATCA representatives, and other research participants,
- Collection and distribution of the participant data to interested members cited in RMP,
- Data analysis and selection of the best metric(s), and
- Final report preparation.

8.2. Air Traffic Services Operations Integration

Air Traffic Services Operations Integration (ATP-420) (POC: Don Frenya and Dan Williams) is responsible for the following:

- Approval of the DD Phase II plan,
- Provision of adequate funding for the study,
- Coordination with NATCA and ATX for MOU development,
- Coordination with NATCA and ATX to identify facility level point of contacts,
- Facility coordination for site visits and data collection issues, and
- Programmatic support to ACT-540.

8.3. Architecture and System Engineering

Architecture and System Engineering (ASD-130) (POC: Steve Bradford) is responsible for the following:

- Approval of the DD Phase II plan,
- Close coordination with ATP-400 to ensure needs are satisfied,
- Management of programmatic issues, and
- Provision of adequate funding for the study.

8.4. Air Traffic Labor Management Relations Division

The Air Traffic Labor Management Relations Division (ATX-500) (POC: Carla Marx and Heather Biblow) is responsible for the following:

- Management of labor-related issues,
- Coordination with national and local NATCA and development of NATCA MOU,
- Coordination with facilities to ensure adequate support for the study, and
- Coordination with ACT-540 to address any potential problems.

8.5. NASA Ames Research Center

NASA Ames Research Center (POC: Banavar Sridhar) is responsible for the following:

- Participation in metric development and validation activities,
- Provision of resources for the study as needed,
- Provision of FACET and CTAS support as needed,
- Coordination of activities with ACT-540 to generate a joint product, and
- Provision of funding as necessary.

8.6. Metron

Metron (POC: Chris Brinton) is responsible for the following:

- Support to various steps of the study related to data sources, data collection, recording and storage of data, and analysis of data,
- Generation of CTAS CM_Sim files with optional parameters,
- Development of limited CTAS site adaptations as necessary,
- Conversion of SAR to CTAS CM_Sim files for sites that are not equipped with CTAS,
- Support of ETMS data collection and extraction,
- Integration of DD metrics into one software, and
- Analysis and comparison of the DD metrics.

8.7. National Air Traffic Control Association

The National Air Traffic Control Association (NATCA) (POC: Joseph Berry) is responsible for the following:

- Provision of national level representation,
- Provision of local facility level representation, and
- Coordination with ACT-540, ATX, and ATP to develop the MOU and conduct the study.

ACRONYMS

ACES	Adaptation Control Environment System
ACT-540	NAS Advanced Concepts Branch
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
CTAS	Center-TRACON Automation System
DART	Data Analysis and Reduction Tool
DD	Dynamic Density
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FACET	Future ATM Concept Exploration Tool
MOU	Memorandum of Understanding
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Control Association
NTAP	National Track and Adaptation Program
RMP	Research Management Plan
RTCA	Radio Technical Commission for Aeronautics,
SAR	System Analysis and Recording
SATORI	Systematic Air Traffic Operations Research Initiative
SOP	Standard Operating Procedures
TMU	Traffic Management Unit
WJHTC	William J. Hughes Technical Center

GLOSSARY

Dynamic Density	Collective effect of all factors that contribute to sector level air traffic complexity or difficulty.
Factor	Reason that contributes to complexity. Generally, factors are observable but may or may not be directly measurable (e.g., weather, arrival rate).
Metric	Computation comprised of one or more variables.
Taskload	Demands imposed on a task (e.g., number of aircraft being controlled).
Validation	Process that ensures a measurement (e.g., variable or metric) actually measures what it is supposed to measure.
Variable	Measurement of the contribution of one or more factors. Variables are measurable (e.g., aircraft count, arrival rate).
Workload	Combined cognitive and physical demands experienced by an operator. The workload experienced by an operator depends on the task, skill, knowledge, experience, abilities, and training. Generally, workload is considered as an operator's response to taskload. For the same taskload, different operators may experience different workload depending on their skill, experience, and other factors.

REFERENCES

Breitler, A., L, Lesko, M. J., Kirk, K. M., 1996, Effects of Sector Complexity and Controller Experience on Probability of Operational Errors in Air Route Traffic, CAN Corporation, Task 9, FAA Contract DTFA01-95-C-00002.

Chatterji, G. B., Sridhar, B, 1997, Measures of Airspace Complexity, Preliminary Draft and Unpublished Work, NASA Ames Research Center.

EuroControl.

Knecht, W., Smith, K., and Hancock, P.A., 1996, A dynamic conflict probe and index of collision risk, Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting.

Kopardekar, P., and DiMeo, K, 1997, Dynamic Density Variables, PowerPoint Briefing.

Kopardekar, P. 2000, Dynamic Density – A Review of Proposed Variables.

Laudeman, I.V., Brasil, C. L., and Branstrom, R. 1996, Air Traffic Control in Restructured Airspace: A Study in Tactical Decision-Making, Power point presentation.

McNally, B.D., Laudeman, I.V., Mayhugh, B., 1997, Field Test Evaluation Plan for a Conflict Prediction and Conflict Resolution System, NASA Ames Research Center.

Magyarits, S.M., and Kopardekar, P. 2000, Dynamic Density: The Measure of Air Traffic Control Sector Complexity, NAS Advanced Concepts Branch.

Mogford, R.H, Guttman, J.A., Morrow, S. L., and Kopardekar, P, 1995, The complexity construct in Air Traffic Control: A review and Synthesis of the Literature, DOT/FAA/CT-TN-95/22, FAA Technical Center: Atlantic City.

NAS Advanced Concepts Branch, 2000, Dynamic Density Metric Development and Validation, Research Management Plan for Dynamic Density.

Position Classification for Air Traffic Control, Series ATC 2152, 1997, Draft.

RTCA Task Force 3 Free Flight Implementation Report, 1995, RTCA: Washington DC.

Sridhar, B., Seth, K. S., Grabbe, S., 1998, Airspace Complexity and its Application in Air Traffic Management, 2nd USA/Europe Air Traffic Management R&D Seminar.

Wyndemere, 1996, An Evaluation of Air Traffic Control Complexity, Final Report, Contract Number NAS2-14284 (NASA contract).

Appendix A

Facility Checklist for Sector Selection

DD Phase II Study Data Collection Checklist

Step 1. Traffic sample identification.

Before:

- ✓ Select 3 specialization areas
- ✓ Select 3 sectors from each specialization area
  - ❖ High altitude sector
  - ❖ Low altitude sector
  - ❖ Either high or low
- ✓ Compile the following documentation:
  - ❖ SOPs and LOAs
  - ❖ Sector maps and lat/longs
  - ❖ Location of VORs, DME, terrain
  - ❖ Routes, jetways, crossing points within sectors, SUA description
  - ❖ Point of tangency
  - ❖ Location of surveillance equipment

During:

- ✓ Select 2 thirty-minute traffic samples from each sector (total of 18 traffic samples)
  - ❖ Ensure that **all** traffic samples contain *moderate to heavy* traffic
  - ❖ Ensure that **some** traffic samples contain:
    - ❖ *increasing* traffic
    - ❖ *decreasing* traffic
    - ❖ *steady* traffic
    - ❖ *weather* and *reroutes*
- ✓ Record the number of controllers on position and any changes to that number over the course of each traffic sample (1 to 2, 2 to 3, 3 to 2, & 2 to 1)
- ✓ Record weather events, if any, and sector areas that were unusable as a result for each traffic sample
- ✓ Record SUA activation, if any, during each traffic sample
- ✓ Determine if monitor alert parameter was exceeded in each traffic sample and record

After:

- ✓ Collect corresponding SAR tapes for each traffic sample
- ✓ Collect corresponding audio tapes for each traffic sample

- ✓ Collect ACES input and output tapes (only once for sector configuration)
- ✓ Collect TMU logs for each traffic sample
- ✓ Collect supervisor sign-in/sign-out sheets for each traffic sample
- ✓ Collect as much data as possible from facility meteorologist corresponding to the 18 traffic samples
- ✓ Collect CTAS CM Sim files for each of the 18 samples (may be coordinated through ACT-540 and facility)

Please use the table provided on the last page of this document to serve as a checklist for the above items.

Step 2. SATORI tape development.

- ✓ Develop 18 SATORI files - one corresponding to each selected traffic sample.

Step 3. Complexity rating data collection.

ACT-540 will conduct this portion of the study on-site at participating ARTCCs. We are requesting participation from a total of 18 individuals (9 controllers and 9 supervisors) from each facility over a 3-day period, as depicted in the following table.

Day 1	Day 2	Day 3
Area 1	**Area 2**	**Area 3**
3 Controllers 3 Supervisors	3 Controllers 3 Supervisors	3 Controllers 3 Supervisors

Traffic Sample Identification Checklist

For easier record keeping, please use this table to track scenario characteristics and data source collection status.

Traffic Sample	Sector	Sector type		Area	Start & end time	Traffic type			Weather and reroutes		SUA activation		SAR tape collected	Audio tape collected	TMU log collected	SISO log collected	Number of controllers	CTAS CM SIM file	Weather data collected
1		H	L			D	S	I	Y	N	Y	N							
2		H	L			D	S	I	Y	N	Y	N							
3		H	L			D	S	I	Y	N	Y	N							
4		H	L			D	S	I	Y	N	Y	N							
5		H	L			D	S	I	Y	N	Y	N							
6		H	L			D	S	I	Y	N	Y	N							
7		H	L			D	S	I	Y	N	Y	N							
8		H	L			D	S	I	Y	N	Y	N							
9		H	L			D	S	I	Y	N	Y	N							
10		H	L			D	S	I	Y	N	Y	N							
11		H	L			D	S	I	Y	N	Y	N							
12		H	L			D	S	I	Y	N	Y	N							
13		H	L			D	S	I	Y	N	Y	N							
14		H	L			D	S	I	Y	N	Y	N							
15		H	L			D	S	I	Y	N	Y	N							
16		H	L			D	S	I	Y	N	Y	N							
17		H	L			D	S	I	Y	N	Y	N							
18		H	L			D	S	I	Y	N	Y	N							

Record your comments below:

Any questions, please contact Sherri Magyarits (609-485-8639)

Appendix B

Participant Consent Form

DYNAMIC DENSITY STUDY

PARTICIPANT CONSENT FORM

I, ______________________________, understand that the Federal Aviation Administration (FAA) Air Traffic Services Division *sponsors* this study and that Ms. Sherri Magyarits of the FAA's National Airspace System Advanced Concepts Branch (ACT-540) *directs* this study, entitled Dynamic Density: Phase II.

<u>Nature and Purpose:</u>

I voluntarily agree to participate in the Dynamic Density Phase II project. I understand the purpose of the study is to collect subject matter expert ratings and other input from me on air traffic complexity at the sector level in the en route environment. I have been briefed that the goal of the study is to develop and validate a quantitative dynamic density metric(s) that accurately measures and predicts sector complexity.

I understand that my participation will consist of one 8-hour day for this study. I will be one of a group of participants consisting of at least three full performance level controllers and three area supervisors.

<u>Experimental Procedures:</u>

I understand that the study will emulate real air traffic control conditions formatted for replay on the Systematic Air Traffic Operations Research Initiative (SATORI) system. I will observe these replays and to the best of my ability make ratings on the complexity of the sector when prompted.

<u>Discomforts and Risks:</u>

I understand that no discomforts or risks are associated with this experiment.

<u>Benefits:</u>

I understand that the only direct benefit to me is to participate in the research. Indirectly, participants and the ATC system as a whole will benefit from the study if a validated dynamic density metric is developed.

<u>Participant Responsibilities:</u>

During the study, it will be my responsibility to observe and rate simulated air traffic as if I was watching live traffic. I will answer all questions presented to me during the experiment to the best of my abilities. I will not discuss the content of the experiment with anyone prior to the conclusion of the experiment. I will complete a Background Questionnaire at the beginning of the study and a Post Run Questionnaire at the end of each scenario.

Participant's Assurances:

I understand that my participation in this study is completely voluntary. The DD researchers have adequately answered all questions I had about the study, my participation, and the procedures involved. I understand that the DD researchers will be available to answer any questions concerning procedures during this study. If new findings develop during the course of this research that may relate to my decision to continue participating, I will be informed.

I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that records of this study are strictly confidential and that I will not be identifiable by name or description in any reports or publications about this study. Photographs and audio recordings made during the study are for use by researchers at the William J. Hughes FAA Technical Center (WJHTC) only. Any of the materials that may identify me as a participant cannot be used for purposes other than internal to the WJHTC without my written permission.

I understand that I can withdraw from the study at any time without penalty or loss of benefits to which I may be entitled. I also understand that the researchers directing this study may terminate my participation if they feel it is in my best interest.

If I have questions about this study or need to report any adverse effects from the research procedures I will contact Sherri Magyarits at (609) 485-8639.

I have read this Participant Consent Form and understand its contents. I freely consent to participate in the DD Phase II study under the conditions described herein. I have received a copy of this Participant Consent Form.

Research Participant: ____________________________Date: _____________

Research Director: ______________________________Date: _____________

Witness: _______________________________________Date: _____________

Appendix C

Background Questionnaire

DYNAMIC DENSITY STUDY

PARTICIPANT BACKGROUND QUESTIONNAIRE

Date:__________________________ ARTCC:______________________

Participant Code:_______________ Area:_________________________

Sector:________________________

1. Please indicate your current position.

   Supervisor Air Traffic Control Specialist

2. What is your total experience as an Air Traffic Control Specialist (in any position or location)?

   Years: _________ Months: _________

3. What is your total experience as a Full Performance Level controller at the ARTCC where you currently work?

   Years: _________ Months: _________

4. *(Supervisors only)* What is your total experience as an Area Supervisor (in any area)?

   Years: _________ Months: _________

5. *(Supervisors only)* What is your total experience as an Area Supervisor in the area where you currently work?

   Years: _________ Months: _________

6. *(Supervisors only)* How many hours per week do you typically supervise this area?

   Hours: _________

7. Traffic Management Unit (TMU) experience

Appendix D

Post-Run Questionnaire

DYNAMIC DENSITY STUDY

PARTICIPANT POST RUN QUESTIONNAIRE

Participant Code:_________________ Date:_____________________

ARTCC:________________________ Area:_____________________

Run Identifier:____________________ Sector:____________________

1. Did you observe any non-routine traffic situations in this scenario? (e.g., lost communications, equipment failure, emergency, etc.)

   Yes No

   If yes, please explain the situation and possible cause.

____

____

____

____

2. On a 1 to 7 scale, how do you rate the overall air traffic complexity of this scenario? (circle one)

1	2	3	4	5	6	7
Very Low Air Traffic Complexity			Moderate Air Traffic Complexity			Very High Air Traffic Complexity

3. How would you describe the traffic flow during this scenario?

   Increasing

   Decreasing

   Steady

   Other (please explain) ________________________

4. Please list the factors that contributed to the complexity of the traffic scenario you just observed. Rate these factors on a 1 (very low) to 7 (very high) scale for their contribution to sector complexity.

Factor	Rating

Appendix E

Daily Schedule

Time	Event
7:00-8:00AM	Briefing/Training
	Background Questionnaire
8:00-8:15	Break
8:15-8:45	Run 1
8:45-9:00	Questionnaire
	Break
9:00-9:30	Run 2
9:30-9:45	Questionnaire
	Break
9:45-10:15	Run 3
10:15-10:30	Questionnaire
	Break
10:30-11:00	Run 4
11:00-12:15	Questionnaire
	Lunch
12:15-12:45	Run 5
12:45-1:00	Questionnaire
	Break
1:00-1:30	Run 6
1:30-1:45	Questionnaire
	Break
1:45-3:00	Debriefing

Notes:

*8-hour working day is assumed with one-hour meal break.

**Data collection can be conducted during any 8-hour shift (i.e., first, second, or mid-night).

Appendix F

Memorandum of Understanding

Memorandum of Understanding
Between the
National Air Traffic Controllers Association
And the
Federal Aviation Administration

This Agreement is made by and between the National Air Traffic Controllers Association ("NATCA" or "the Union") and the Federal Aviation Administration ("FAA" or "the Agency"), collectively known as the Parties. This Agreement represents the complete understanding of the Parties at the national level concerning **Phase II of the Dynamic Density Study at Los Angeles ARTCC, Denver ARTCC, Fort Worth ARTCC, Atlanta ARTCC and Cleveland ARTCC.**

Section 1. In accordance with article 48 of the joint collective bargaining agreement (CBA), the Union may designate one (1) bargaining unit employee (BUE) to serve as the NATCA National Dynamic Density Representative. Said representative will provide technical expertise and identify potential impact on BUEs. Said representative shall be afforded a reasonable amount of duty time to perform the duties of this Agreement. The Agency shall provide travel and per diem for any travel required by the Agency in connection with this project.

Section 2. In accordance with article 48 of the joint CBA, the Union may designate one (1) BUE to serve as the NATCA Local Dynamic Density Representative at each facility involved in the study. Said representatives will provide technical expertise, identify potential impact on BUEs, and participate in the review of Situation Assessment Through Recreation Of Incidents (SATORI) data at the local level. Said representatives shall be afforded a reasonable amount of duty time to perform the duties of this Agreement. The Agency shall provide the local representatives travel and per diem for any travel required by the Agency in connection with this project.

Section 3. The NATCA National Dynamic Density Representative shall be afforded duty time, travel and per diem for participation in the study preparation and data reduction work group at the William T. Hughes Technical Center. The Parties at the facility level will determine the process to be used to select BUE participants in the facility level portion of the study.

Section 4. Both Parties recognize the sole purpose of Phase II of the Dynamic Density Study is to determine and refine parameters and procedures for a Dynamic Density formula. The SATORI program will be the principal tool utilized in the study to analyze the Dynamic Density formula. Information learned from SATORI while preparing for and conducting the study shall not be used to initiate an operational error/deviation investigation.

Section 5. This Agreement may be re-opened by either Party in accordance with the provisions of Article 7 of the collective bargaining agreement ("CBA"). This Agreement does not constitute a waiver of any right guaranteed by law, rule, regulation or contract on behalf of either Party.

Section 6. This Agreement will terminate upon the completion of Phase II of the Dynamic Density Study. The Agency will provide the results of the study to the Union.

Section 7. In accordance with Article 49, Section 2 of the CBA, before entering Phase II of the study, the Union and the employees shall receive a document stipulating the conditions under which the study will be conducted and a statement of intent and practice by which data will be held in confidence. The Union shall receive a copy of the study concurrently with its submission to the Employer.

For the Union:	For the Agency:
______________________ Laurie C. Bay Labor Relations Representative	______________________ Donald Frenya ATP-420
______________________ James L. Gordon NATCA ATX Liaison	______________________ Heather Biblow ATX-501
______________________ Wade Stanfield NATCA ATP Liaison	

______
DATE